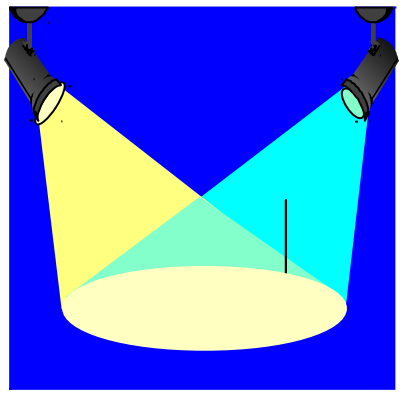
# RISK BASED ANALYSIS



1/5/98

# OBJECTIVES

- Describe risk-based analysis
- Provide an overview of Corps activities in RBA
- Flood Control Application

# RISK-BASED ANALYSIS

"Planners shall identify areas of risk and uncertainty in their analysis and describe them clearly, so that decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative plans."

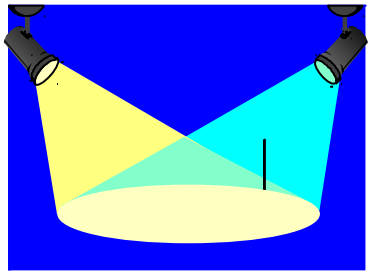
Principles and Guidelines, Paragraph 10, February 1983.

# Risk - Based Analysis

An approach to evaluation and decision making that explicity, and to the extent practical, analytically incorporate considerations of risk and uncertainty.

# RISK-BASED ANALYSIS

## BASIC CONCEPTS



1/5/98

# RISK

- Determined by occurrence probability of an event.
- Magnitude:  0 to 1
- Examples:

  Probability of being flooded.

  Probability of unsatisfactory performance

# UNCERTAINTY

- True value of variables not known.
- Values can take on a range.
- Leads to errors in estimates.

# PROBABILITY DISTRIBUTION (Probability Density Function, PDF)

Defines the occurrence probability for a particular random variable.

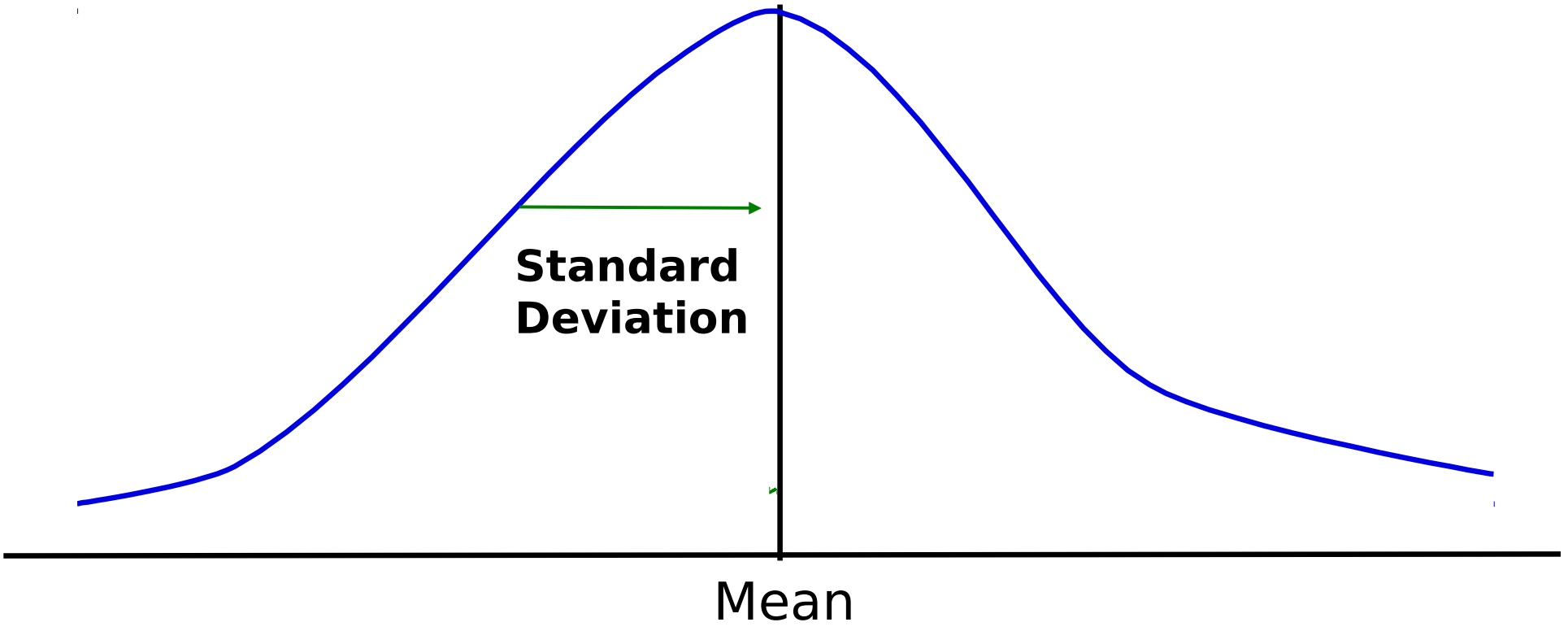
Random variable - outcome or value can not be predicted before event takes place.

Parameters that define distribution are derived from sample data.

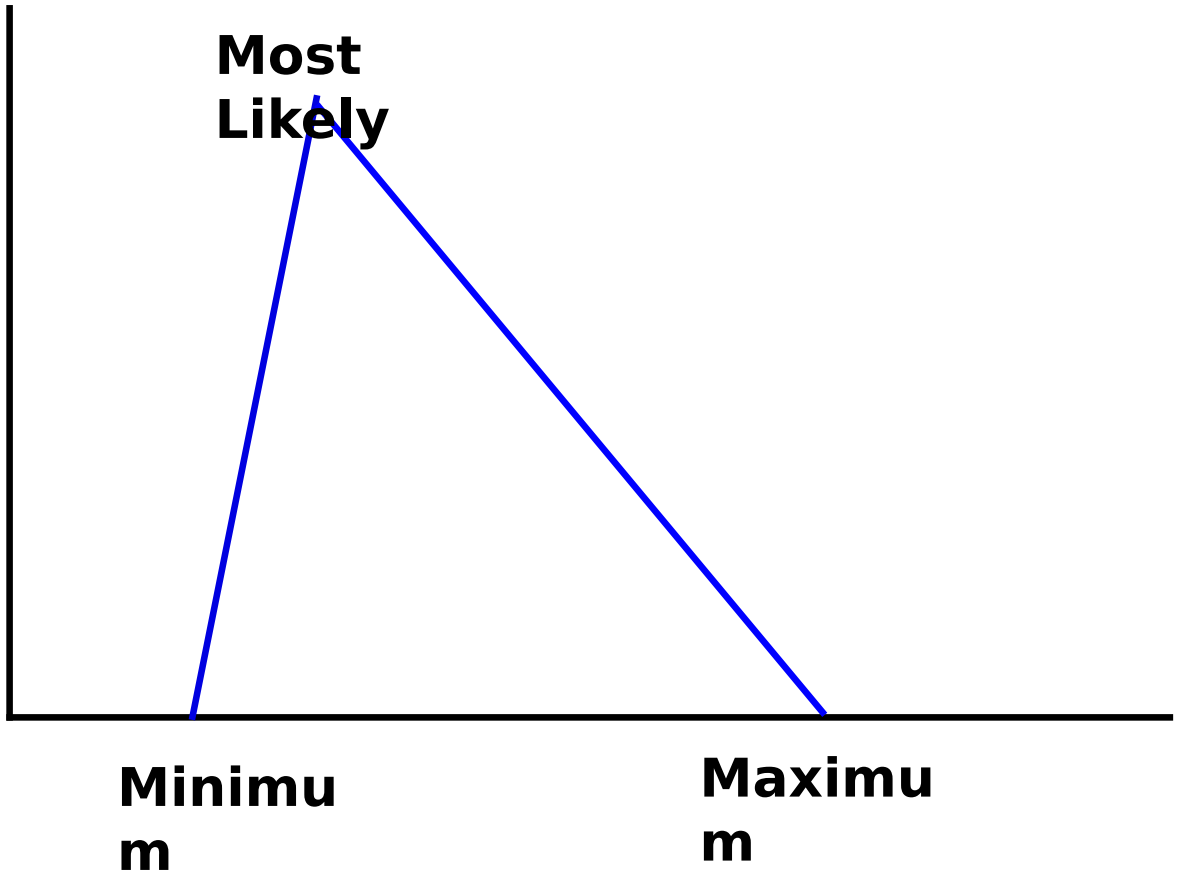
# EXAMPLES PDF

- Normal Distribution
- Triangular Distribution
- Lognormal Distribution

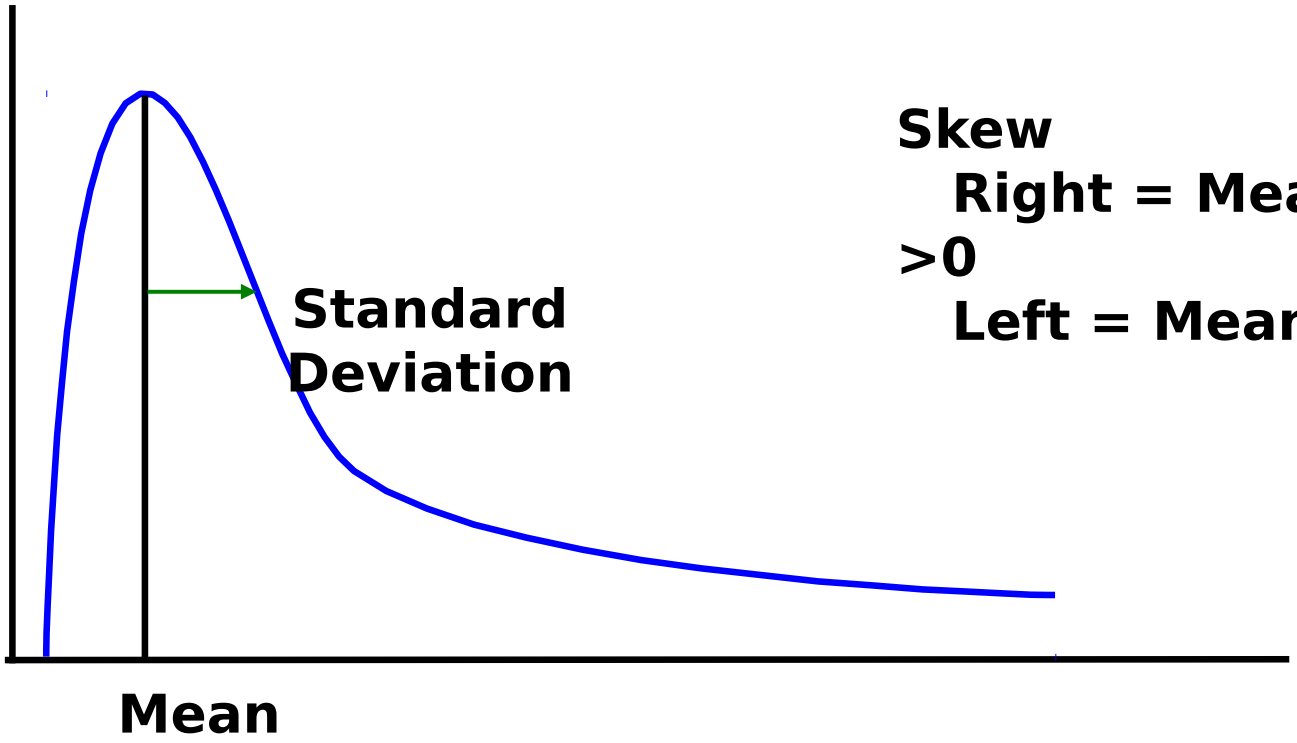
# NORMAL DISTRIBUTION



# TRIANGULAR DISTRIBUTION



# LOGNORMAL DISTRIBUTION




**Skew**
**Right = Mean-Mode >0**
**Left = Mean-Mode<0**

# CENTRAL VALUE STATISTICS

Mode = most frequently occurring

Median = middle of ranked list

MEAN (Expected value) = $\frac{\text{sum of values}}{\text{number of values}}$

Computation: $\bar{X} = (1/N)\sum_{i=1}^{N} Xi$

# DISPERSION STATISTICS

Standard deviation, $\sigma$ = average deviation from

the mean

Variance = (standard deviation, $\sigma$)$^2$

# MONTE CARLO SIMULATION

Numerical integration technique to approximately
derive the distribution of a random variable (Q), given:

1. The behavior of variable Q is determined from contributing variables X, Y, and Z.

2. A function or relationship giving the value of Q knowing the values of X, Y and Z.

3. The probability distributions of X, Y and Z.

# EXAMPLE

Flood Control Study:

Q = Stage-Damage Curve

X = Stage-Discharge Curve
Y = First Floor Elevation
Z= Structure Values

# RISK-BASED ANALYSIS

- Major Rehabilitation Studies:
  - Inland Navigation
  - Hydropower
- Flood Control Studies
- Deep Draft Navigation
- Storm Damage Prevention Studies

# RISK BASED ANALYSIS

## MAJOR REHABILITATION PROGRAM

1/5/98

# MAJOR REHABILITATION PROGRAM

- Inland Navigation and Hydropower

- Guidance:
  - Guidance for Major Rehabilitation Projects (17 Aug 93, updated annually)
  - ETL 1110-2-532, dated 1 May 92 Reliability Assessment of Navigation Structures

# HIGHLIGHTS

- Funded under CG Appropriation (FY93)
- Must Compete For New Start Funding

# QUESTIONS

To rehab or not to rehab?

Is rehab really needed now?

What is the best rehab option?

Will future lossess offset investment?

# METHODOLOGY

- Combine:
  - Probability Theory
  - Structure Condition
  - Statistical Data
  - Engineering Judgement

- Into a consistent method for prioritizing the investments needed to assure an acceptable level of reliability.

# INLAND NAVIGATION

- VARIABLES:
  - Commodities forecasts
  - Unplanned closures - delay costs
  - System Capacity
  - Fleet characteristics
  - Foundation conditions
  - Cross-currents in approach channels
  - Filling rates
  - Climatic conditions
  - Environmental windows
  - Competing uses
  - High/Low flows

# INLAND NAVIGATION GUIDANCE

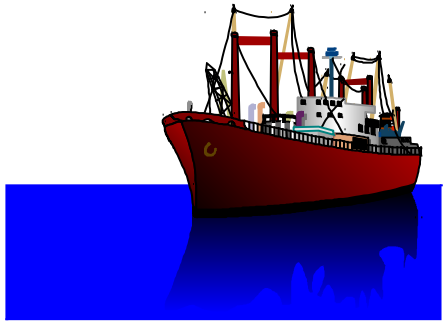
- Draft EC released to the field 5 August 1996
- Draft Report "Incorporating Risk and Uncertainty in Commodity Forecasts"

# HYDROPOWER

- RELIABILITY
  - Restore units back to original design condition
- EFFICIENCY IMPROVEMENTS
  - Production over original design condition

# RISK-BASED ANALYSIS

## DEEP DRAFT NAVIGATION



1/5/98

# UNCERTAINTY

- NED COSTS:
  - Channel Dimension
  - Maintenance
  - Shoaling/Sedimentation

# UNCERTAINTY

- NED BENEFITS
  - Vessel Traffic
  - Fleet Forecast
  - Commodity Forecast
  - Vessel Operations

# OTHERS

- Vessel Safety
  - Underkeel clearance
  - Passing clearance
- Environmental Risks

# STATUS

- Draft EC distributed internally at HQUSACE
- Literature search, field surveys, framework done
- Contract for commodity fleet uncertainty
- New model for vessel operating costs

# NEXT STEPS

- Field test benefit uncertainty
- Develop/refine operations uncertainty
- Develop/refine engineering uncertainty
- Integrate

# RISK-BASED ANALYSIS

## COASTAL STORM DAMAGES

1/5/98

# STORM RELATED UNCERTAINTY

- Wave Height Frequency
- Stage Frequency
- Erosion
- Duration

# DAMAGE RELATED

- STAGE DAMAG
- LOSS FROM DIRECT WAVE DAMAG
- LOSS FROM UNDERMINING

# OTHER UNCERTAINTY

- LONG TERM EROSION
- OTHERS

# COASTAL STORM MODEL

- Developed by Wilmington District
- Life Cycle Analysis
- Monte Carlo Simulations

# NEXT STEPS

- Draft EC circulated
- Finalize

# RISK-BASED ANALYSIS

## FLOOD CONTROL

1/5/98

# Guidance (cont.)

- Flood Control  EC 1105-2-205

  "Risk-based analysis for Evaluation of Hydrology/hydraulics and Economics in Flood Damage Reduction Studies"

# Flood Control EC Highlights

- Risk-based analysis required for:
  - Feasibility Reports
  - General Design Memoranda
  - General Reevaluation Reports
  - Section 205 Detailed Project Reports
  - No Grandfather Clause

# Flood Control Highlights (cont.)

- PSP will describe methods to quantify uncertainties of key variables.
- NED still the rule.

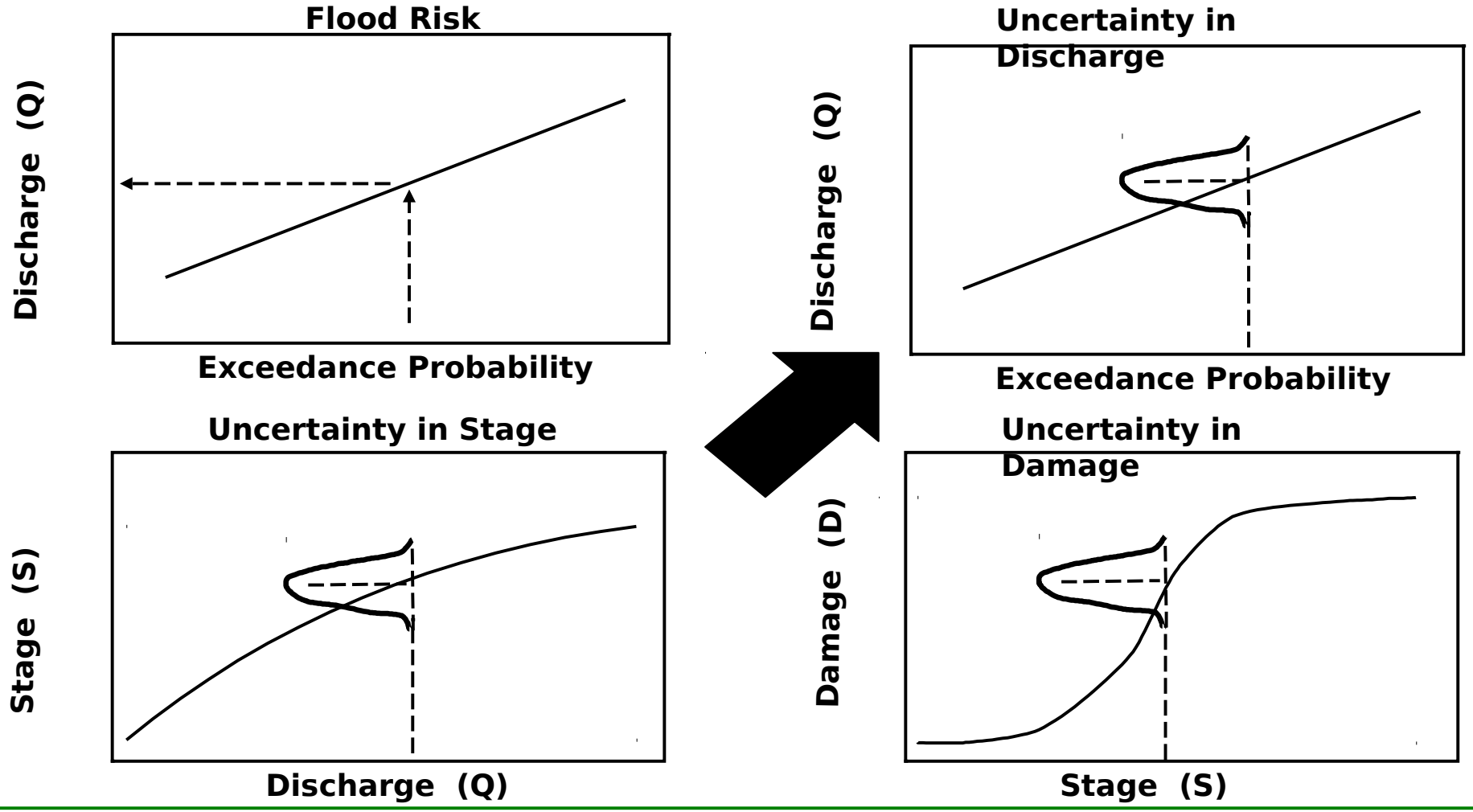
# Flood Control Highlights (cont.)

- The  term or concept of "*freeboard*" will no longer be used.
- The term or concept of "*level of protection*" will no longer be used.
- Procedures for applying Risk-Based Analysis

# HYDROLOGIC REQUIREMENTS FOR RISK-BASED ANALYSIS

- Best Estimates of Discharge-Frequency
- Uncertainty Distribution as a Function of Discharge Exceedence Frequency

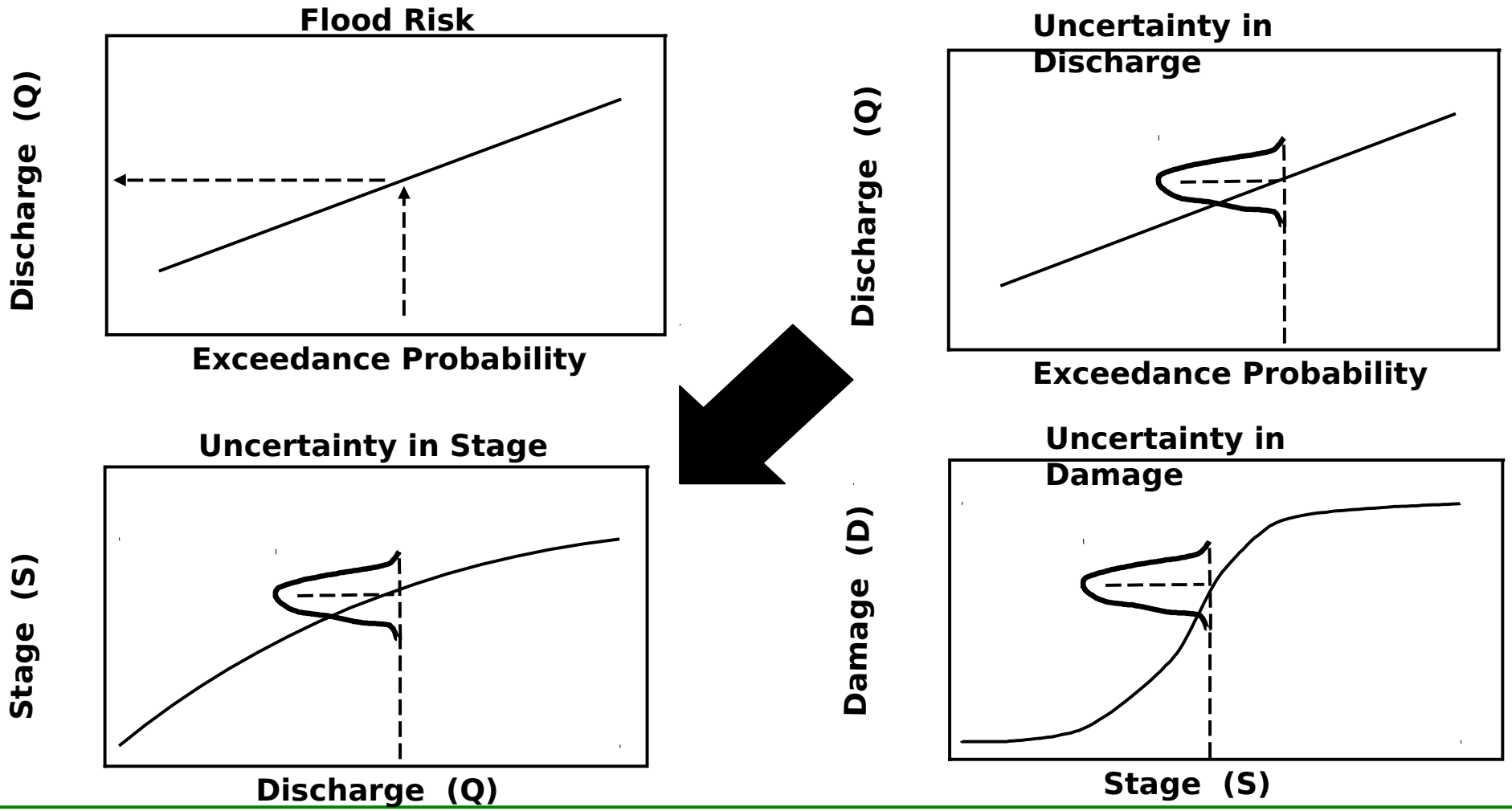
# DISCHARGE UNCERTAINTY



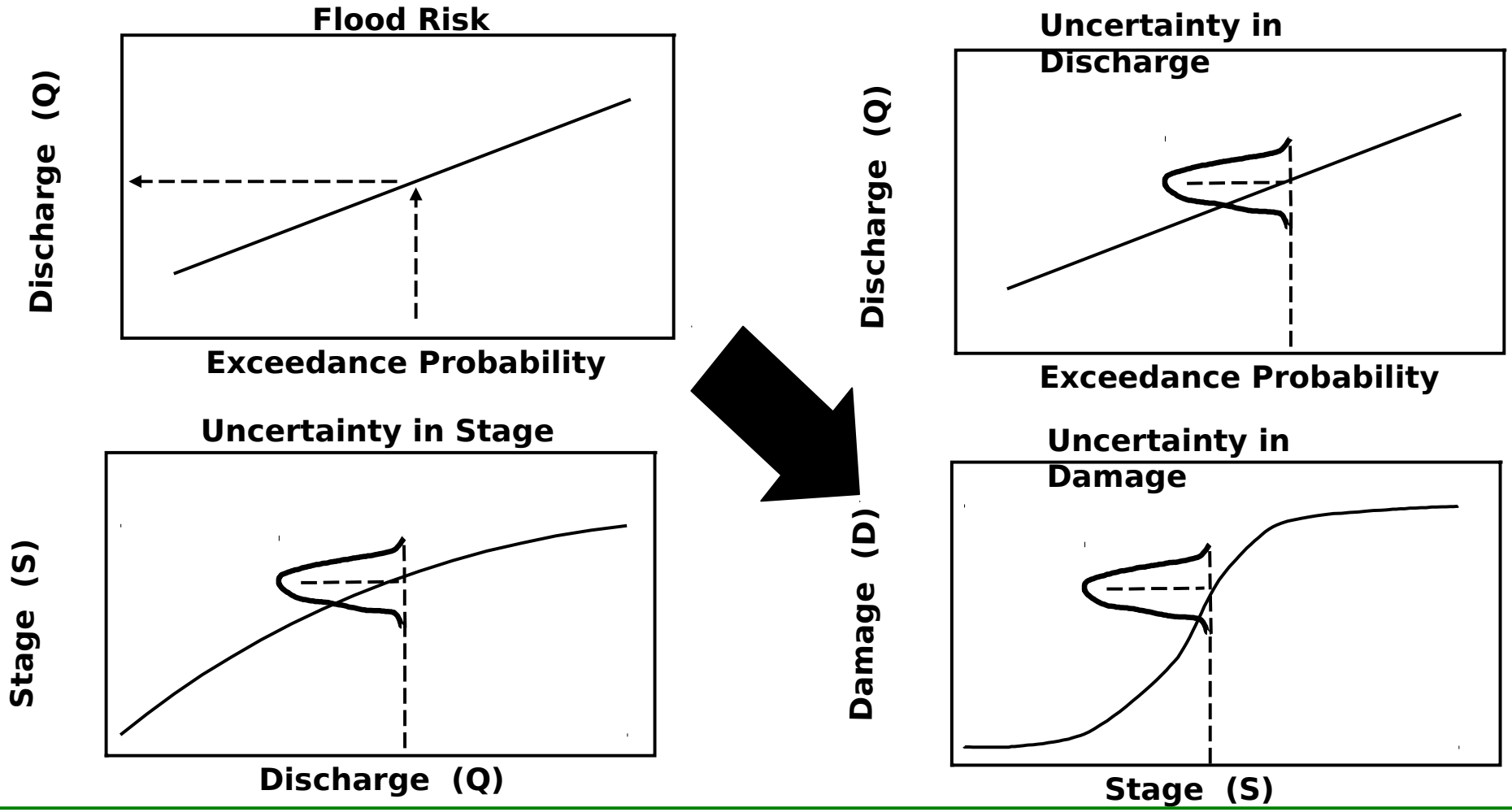
# HYDRAULIC REQUIREMENTS FOR RISK-BASED ANALYSIS

- Best Estimates of  Stage-Discharge
- Uncertainty Distribution as a Function of Discharge

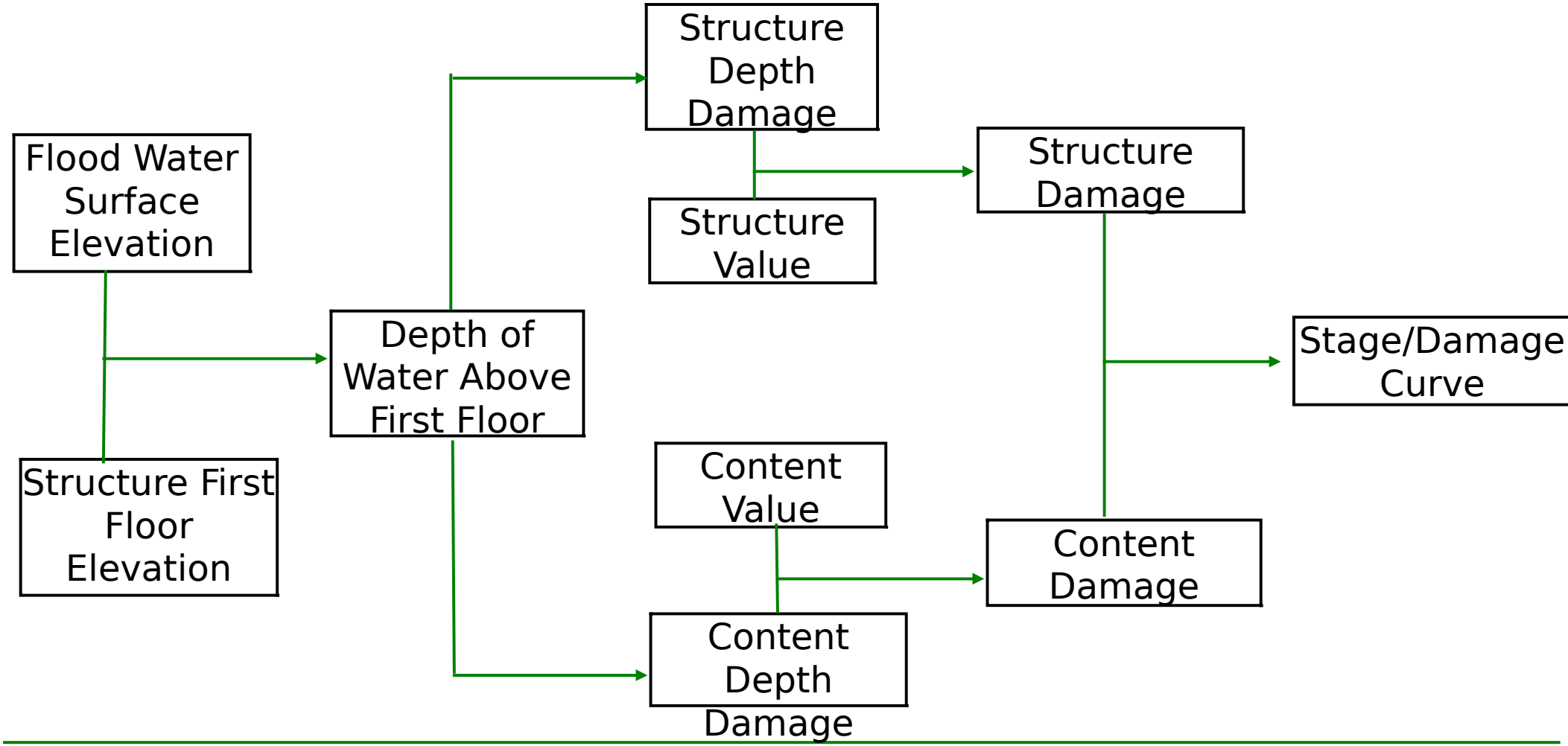
# STAGE UNCERTAINTY



# RISK BASED APPROACH



# FLOOD DAMAGE ANALYSIS



# STRUCTURE VALUE UNCERTAINTY

Techniques:

- Replacement cost estimating
- Real estate assessment
- Recent sale prices

Error:

- Perform statistical analysis of sample data:
  - Estimate mean, standard deviation (error), etc.

- Based on professional judgement.

# CONTENT VALUE UNCERTAINTY

Content value to structure value ratio.

Insurance data = 50% to 75%

Guidance: based on survey data.

# CONTENT TO STRUCTURE VALUE RATIO (STATISTICS)

| Structure Type | Me | Standard | Minim | Maximu |
|---|---|---|---|---|
| One story - no | 0.4 | 0.250 | 0.100 | 2.497 |
| One story - basement | 0.4 | 0.217 | 0.100 | 2.457 |
| Two story - basement | 0.4 | 0.248 | 0.100 | 2.500 |
| Mobile home | 0.6 | 0.378 | 0.102 | 2.474 |

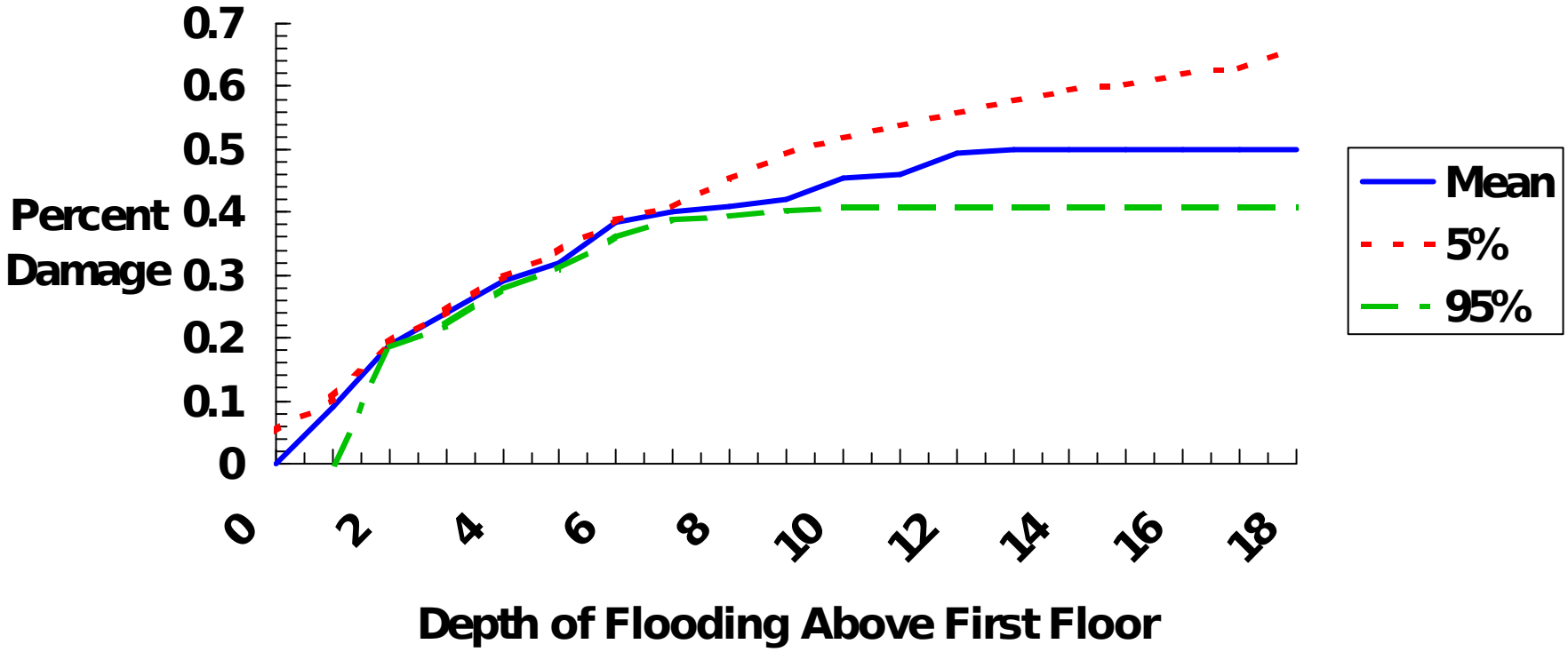
# FIRST FLOOR ELEVATION

| Method | Contour Interval (feet) | Error | Standard Deviation |
|---|---|---|---|
| Field Survey | | | |
| Hand level | NA | 0.2 @ 50' | 0.10 |
| Automatic | NA | 0.03 @ | 0.02 |
| Aerial Survey | | | |
| | 2 | 0.59 | 0.30 |
| | 10 | 2.94 | 1.50 |
| Topographic | | | |
| | 5 | 2.94 | 1.5 |

# DEPTH-DAMAGE RELATIONSHIP

- Hydrologic Variables:  Velocity, Duration, Sediment, Frequency
- Structural Variables: Building materials, Condition, Age, Content Location

# STRUCTURE DAMAGE



# SIMULATION MODELS

- Available:  LOTUS and @RISK template
- Future:  New application - HEC, IWR and WES

# RISK MODEL

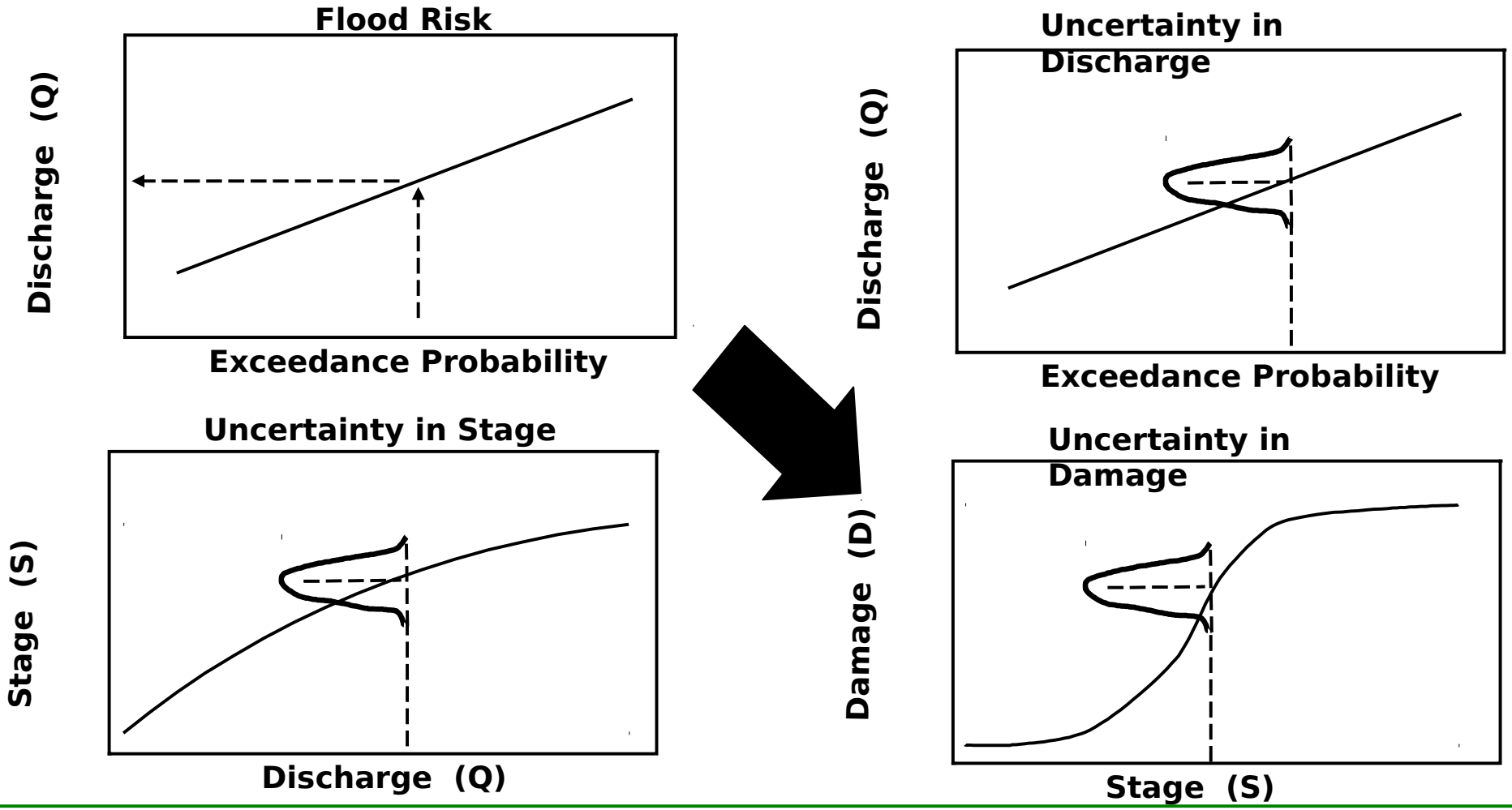
- PROJECT SIZING
- RELIABILITY

# RISK MODEL

- Project Sizing:

  Determine expected annual damage (benefits) for any project size with uncertainty.

# RISK BASED APPROACH



# RISK-BASED LEVEE SIZING

| Median Exceedance Probability | Top of Levee | Benefits | Cost | Net Benefits |
|---|---|---|---|---|
| 1.0 | | | | |
| .02 | 19.1 | 4.6 | 14.0 | -9.4 |
| .01 | 21.8 | 18 | 19.8 | -1.8 |
| .004 | 25.7 | 45.3 | 30.6 | 14.7 |
| .002 | 27.0 | 65.4 | 37.1 | 28.3 |
| .0014 | 28.7 | 61.7 | 47.6 | 14.1 |

# RISK MODEL

- Reliability

  Determine percent chance of containing (or risk of overtopping) selected design stages given a specific flood discharge occurs.

# RELIABILITY OF LEVEE STAGE

| LEVEE HEIGHT | .01 EVENT |
|---|---|
| 16.5 | 0.3 |
| 19.1 | 9.4 |
| 20.0 | 20.1 |
| 21.8 | 48.4 |
| 24.0 | 75.5 |
| 25.7 | 86.1 |
| 27.0 | 97.5 |

# NED Plan Requirement

- Risk-based analysis does not change the requirement for selecting the NED plan.

# END OF THIS SEGMENT